MA 35, 1991.2: En 27

UMASS/AMHERST
312066016824616

Energy and the Environment: Photovoltaics in the Energy Mix

Jane M. Weissman
Director
Massachusetts Photovoltaic Center

> *"Driving our energy choices solely on costs without regard for environmental consequences is unacceptable."*

It is most appropriate that as we begin the 1990s, we are discussing the role of solar electric power in the context of developing strategies to meet current and future environmental issues. Though the specific consequences of environmental degradation and the build-up of the "greenhouse" gases are uncertain, the evidence strongly suggests that carbon emissions from the burning of fossil fuels are one of the biggest contributors to the greenhouse effect. Electricity generation is a major contributor to this carbon dioxide build-up. As we begin this new decade, there is no doubt that we must rethink how we produce and consume electric power. We must explore alternatives.

Structural and institutional barriers often impede the diffusion of new technologies into the mainstream of society. In spite of their merits and benefits, perceived risks and financial awkwardness beseige new technologies and new processes. It takes time for society, its many users and complicated and cumbersome systems, to become comfortable with changing methods and practices.

This is very much the case as we introduce photovoltaic-powered systems into our energy mix. To look at sunlight as a legitimate generator of electricity requires policy shifts, appropriate incentives, and institutional support. To work toward the point where we can significantly rely on this non-fossil-fuel-based energy source requires not only additional technical advances and improvements, but also the acceptance by and flexibility in our social and political systems.

In the following pages, I will talk about these issues, and where and when and how photovoltaics (PV) -- the direct conversion of sunlight into electricity -- plays and will play a role in our energy mix.

903/385

The tremendous advancements made between 1954 and 1973 brought photovoltaics out of the laboratory and made it an important element of the space program as a light-weight, long-lasting energy source for satellites. Even though the modules were not yet economical, this progress established the credibility of photovoltaic panels for terrestrial applications. With the oil embargo of 1973, the public attention and awareness of energy shortages, and federal support for researching alternative energy sources, efforts to develop photovoltaics as a terrestrial energy source began in earnest.

Although still expensive, photovoltaics was used to power remote telecommunications repeater stations starting in the mid-1970s. Much like the space program, the need was for a reliable power source requiring almost no maintenance, one that could be placed in remote locations. As these small-scaled energy systems matured, numerous advantages became apparent and by the early to mid-1980s, these dispersed photovoltaic systems became known for their favorable characteristics: versatility, reliability, free fuel, modularity, and, very impor-

SMALL-SCALE PHOTOVOLTAIC ENERGY SYSTEMS : ADVANTAGES

VERSATILITY

PV-powered systems are highly adaptable to different tasks and to different geographical circumstances. The sun's energy provides direct output of electricity which can be stored if necessary, and transformed to provide any range of voltages and currents both DC and AC. This power can then be used to drive a variety of devices such as lights, water pumps, communications systems, medical equipment, televisions, radios, and telephones.

RELIABILITY

PV panels are solid-state devices rather than mechanical ones. There are no moving parts. This is especially important in areas where material and personnel required to maintain and repair complicated equipment may be limited.

FREE FUEL

Once installed, the ongoing cost of providing power is virtually zero. Rather than requiring the use and cost of fuel, PV provides a continuing source of power using only energy from the sun.

MODULARITY

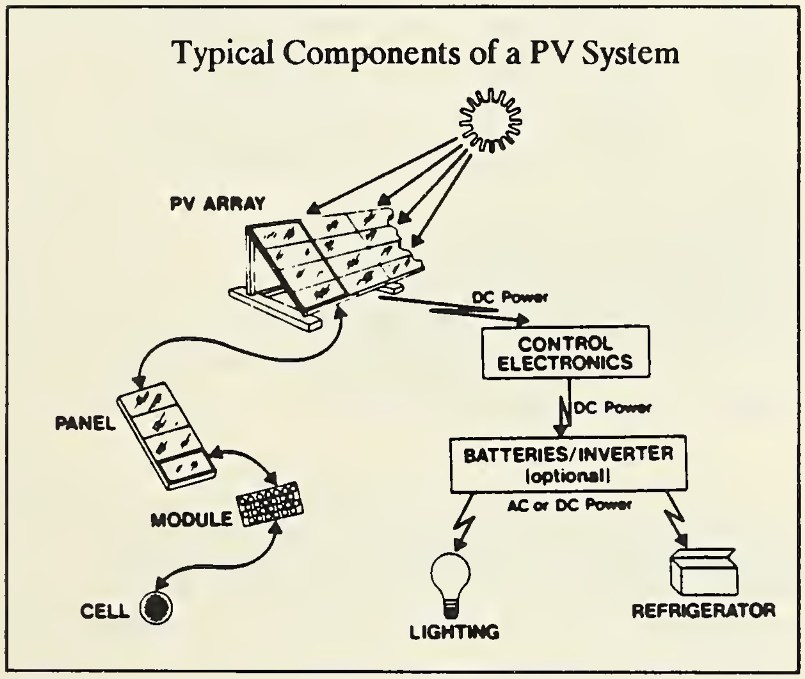
PV systems can be scaled to meet any energy demand. This allows systems to be tailored and designed to satisfy immediate needs. Systems can be economically expanded as demand grows. PV systems are flexible in size and capacity.

ENVIRONMENTALLY SAFE

Photovoltaics is the cleanest, most environmentally benign of any energy source. There are virtually no emissions from combustion. There are no moving parts and no noise pollution other than from motors or end-use devices. There are no visual encumbrances such as light or smoke.

tantly, no negative environmental consequences from their operations.

Today, photovoltaics is the only energy source with broad potential that continues to decline in cost. As a result, the list of PV-powered applications is rapidly expanding. In addition to powering remote communications and navigation equipment, PV is appropriate and cost-effective for stand-alone systems for agriculture, medical care, and general lighting. There are almost 2 billion people in the world without electricity to meet their basic needs. Photovoltaic-powered systems are playing an important role in the planning and project implementation in developing countries.

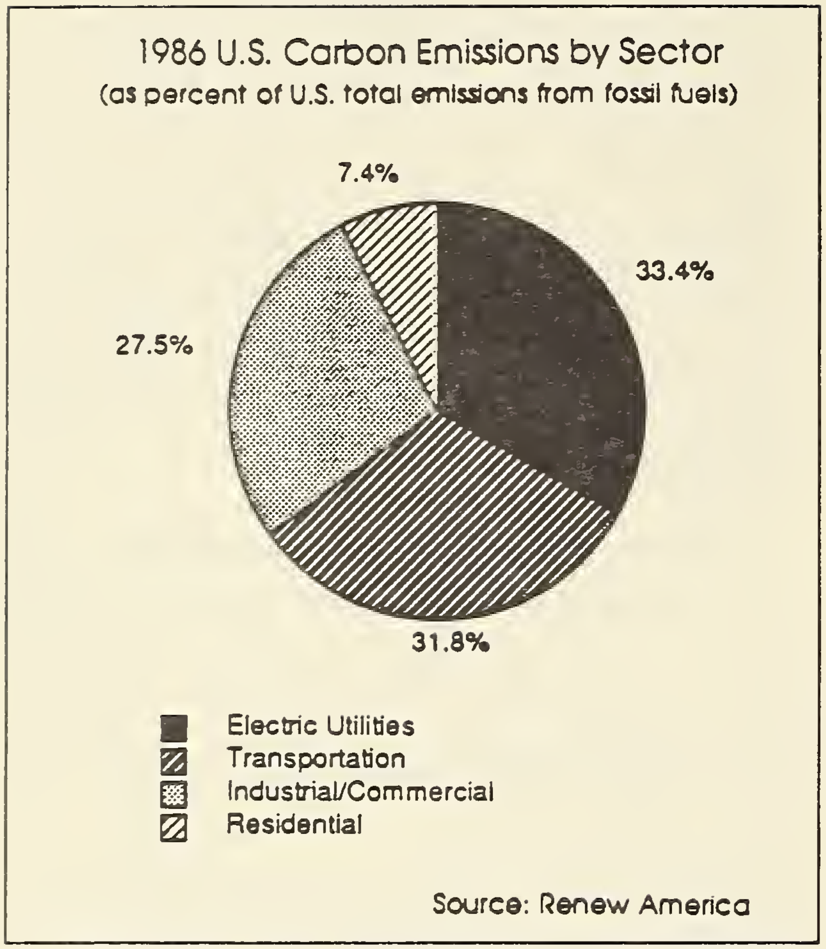


Typical Components of a PV System

Along with its increased role in the planning of sustainable strategies in developing countries, PV systems are increasingly being used closer to home. The Coast Guard operates PV-powered navigational aids, and the Massachusetts National Guard employs PV to trickle charge batteries on emergency vehicles. Many states are now using PV to power highway call boxes and operational signals as well as lighting and other needs in parks and remote areas. In cities, PV-powered lighting is cost-effective for shelters and bus stops. The range of consumer products continues to grow from the early days of solar calculators and watches. There are PV systems for boats, mobile homes, and garden lighting. Expected new consumer products include PV sun-roofs on automobiles to run ventilation systems and PV on portable computers to charge batteries.

Despite its growing potential, during the early and mid-1980s, the development and progress of this technology have been mired down in a negative business and political climate. Low oil and gas prices, a surplus of electric generating capacity, the loss of federal tax credits, the phase-down of federal efforts to stimulate R&D, and the general perception of renewable energy technologies as not fully cost competitive all contributed to a slow-down in development and utilization. Long-term benefits were sacrificed because of short-term policy views. However, fuel prices are now rising. Power shortages are becoming real. PV is experiencing significant technical and manufacturing advances. And environmental concerns are no longer being ignored. Today, how does PV compete with these economic changes and political shifts?

Electricity generation is a major contributor to CO_2 emissions. Approximately thirty-three percent of the U.S. total carbon emissions from fossil fuels comes from electric power plants. Fossil fuel emissions contribute not only to the greenhouse problem but also to urban smog, acid deposition, and stratospheric ozone depletion. Current and future strategies and policies must include limiting the combustion of fossil fuels.


1986 U.S. Carbon Emissions by Sector
(as percent of U.S. total emissions from fossil fuels)

Source: Renew America

Photovoltaics is one strategy to provide energy without negative environmental consequences.

No technology is completely environmentally benign. However, PV is the cleanest, most environmentally benign of any energy source.

As environmental impacts are measured, all stages of energy production have to be considered. There are different capital, fuel, and operating characteristics. The effects of fuel extraction, plant construction, materials fabrication, operation, and decommissioning have to be recognized and factored. Although during cell manufacturing, photovoltaics does require significant one-time inputs of raw material, there are practically no emissions during operation. Compare this to a coal plant which has emissions and resource impacts associated with coal mining, coal transportation, coal plant construction, and electricity generation. Coal produces its most significant emissions during operations.

Not only must we keep in mind the environmental impacts at all stages of the energy production cycle, but we must also look at the hidden costs of energy production. This economic problem is one of externalities, in which the costs related to electric power sources are not directly represented in their market price. These costs result from environmental effects, subsidies, and unquantified risk factors.

If one adds social costs to the traditional capital cost of conventional power, photovoltaics is already generally competitive with coal, oil, and nuclear generated power. Social costs include the health and economic consequences of CO_2 and SO_4, assorted particulates, and radiation. Also included are such risks as fuel cost and availability, nuclear fuel and waste containment, and global warming. Finally, such subsidized costs as our military capability to protect oil supplies, the underwriting of nuclear insurance, and assorted tax breaks for conventional power technologies, all effect the true value of energy.

It is not clear how the social costs of global warming and environmental degradation will be internalized in the price of polluting and nonpolluting options. According to a recent study by Olav Hohmeyer for the Fraunhofer Institute, if all the costs to society are truly accounted for, and added to the cost of generation, photovoltaic energy products would be cost-effective for utility-scale power in the very near future.

However, at this time, there is a marked disparity of advantage accorded conventional power technologies to the detriment of cleaner renewable energy resources. This disparity falsely argues for continued use of conventional energy sources, and restricts the development

Carbon Dioxide Emissions: Electric Technologies

Emissions by Energy Production Stage
(Metric Tons per GWh)

Technologies	Fuel Extraction	Construction	Operation	Total
Conventional Coal Plant	1.0	1.0	962.0	964.0
AFBC Plant +	1.0	1.0	960.9	962.9
IGCC Electric Plant + +	1.0	1.0	748.9	750.9
Oil Fired Plant	-	-	726.2	726.2
Gas Fired Plant	-	-	484.0	484.0
Ocean Thermal Energy Con.	NA	3.7	300.3	304.0
Geothermal Steam	0.3	1.0	55.5	56.8
Small Hydropower*	NA	10.0	NA	10.0
Boiling Water Reactor	1.5	1.0	5.3	7.8
Wind Energy	NA	7.4	NA	7.4
Photovoltaics	**NA**	**5.4**	**NA**	**5.4**
Solar Thermal	NA	3.6	NA	3.6
Large Hydropower	NA	3.1	NA	3.1
Wood(sustainable harvest)	-1509.1	2.9	1346.3	-159.9

+ An Atmospheric Fluidized Bed Combustion (AFBC) plant
+ + An Integrated Gasification Combined Cycle (IGCC) plant
(-) Missing or inadequate data for analysis, estimated to contribute 1%
(NA) Not Applicable
* This analysis considered construction of new dams

Source:
U.S. Department of Energy
Environmental Emissions From Energy Technology Systems: The Total Fuel Cycle.

and utilization of clean energy technologies. Both utility accounting procedures and the regulatory environment create little or no incentives to use renewable and alternative energy sources. There are no rewards for using clean energy.

So then, how does photovoltaics fit into the energy picture for the 1990s?

Peak load power plants are intended to produce power for the periods of highest electrical demand within a particular period of time. Many regions in the United States are characterized by summer peaking electric power demands. The summer peaks tend to occur from mid to late afternoon as the demand for cooling increases. Solar insolation also peaks in the mid-afternoon periods in summer. Photovoltaics provide a good match between solar availability and peak load periods.

Currently, utility peak power generation provides the most expensive and least efficient energy. For large residential customers in the Long Island Lighting Company service area in New York, the average summer daytime rate is 18 cents/kWh. During hot weather, Southern California Edison rates alternate between 1.8 to 140 cents/kWh with the average cost of power during these hot summer days being 37.3 cents/kWh. The cost of PV generated electricity, now 25 cents to 35 cents/kWh, is predicted to fall to 10 to 20 cents/kWh during the next phase of industrial expansion. By accepting photovoltaics as a legitimate and cost-effective supplier of peak power, solar energy can be integrated into the utility sector to provide new and clean sources of peak power as well as to replace aging, costly, and environmentally unsafe peak-power plants. In the United States today, there are already over 200 grid-connected PV systems providing highly reliable peaking power.

In addition to this high-value end of electrical energy generation, PV is now contributing to the utility small power market. As a cost-effective choice, PV-powered applications for this market include line voltage augmentation and all types of monitoring and switching devices. Highway lighting for signs and interchanges and communication repeaters are other applications where a PV system is cost-effective when compared to the cost of a transformer or a transformer and line extension. Photovoltaic systems will also play a role in reducing demand charges for customers who have a low overall energy usage which is highlighted by a relatively short high day-time demand.

Where, how, and when PV fits into our utility energy makeup depends on the intersection of many factors. We are at the point now where we are beginning to see the integration of the technology with policy and regulatory issues. Advancements are being made in the performance efficiency and stability of PV modules. We are seeing the increase of the quality and yield of the manufacturing processes with reduced production costs. The societal value of photovoltaics is beginning to find its way into utility resource planning through least-cost energy planning principles which consider the full social/environmental costs of each energy option.

We can no longer ignore the value of clean energy. Driving our energy choices solely on costs without regard for environmental consequences is unacceptable. When evaluating and selecting our future energy options, responsible planning must incorporate environmental impacts along with the system's cost, efficiency, and reliability calculations.

This paper was part of the official proceedings for the New England Environmental Expo, April 1990, Boston, Massachusetts..

RESOURCES:

Electric Power Research Institute. EPRI Journal. "The Politics of Climate." June, 1988.

Electric Utility Consultants Conference. "Renewable Energy and Its Role in Resolving Current Environmental Concerns." Dr. John Berg, Assistant Secretary, Office of Conservation and Renewable Energy, Department of Energy. September 14, 1989.

Olav Hohmeyer. "Social Costs of Energy Consumption: External Effects of Electricity Generation in the Federal Republic of Germany." Fraunhofer-Institut. 1988.

Interstate Solar Coordination Council. "A Guide to Renewable Energy and Least Cost Utility Planning." Prepared by William R. Meade with David F. Teitelbaum. September, 1989.

National Research Council. Committee on Global Change. Global Change and Our Common Future. Papers from a Forum. "Toward A Global Environmental Policy." William D. Ruckelshaus. 1989.

Public Citizen. "Power Surge: The Status of Near-Term Potential of Renewable Energy Technologies." Nancy Rader. May, 1989.

Renew America. "Reducing the Rate of Global Warming: The States' Role. Prepared by: Sheila Machado, Rick Piltz. November, 1988.

U.S. Department of Energy. "Energy System Emissions and Materiel Requirements." Prepared for the Deputy Assistant Secretary for Renewable Energy, U.S. Department of Energy. Prepared by Meridian Corporation. February, 1989.

U.S. Department of Energy. "Environmental Emissions from Energy Technology Systems: The Total Fuel Cycle." Dr. Robert L. San Martin, Deputy Assistant Secretary for Renewable Energy, U.S. Department of Energy. Spring, 1989.

U.S. Department of Energy. "Investing In Success." Photovoltaic Energy Technology Division. January, 1989.

U.S. Department of Energy. "Review of the U.S. Photovoltaics Industry: Trip Report." November, December, 1988.

The Massachusetts Photovoltaic Center
Office of Business Development
100 Cambridge Street, 13th Floor
Boston, MA 02202
617-727-3206